

Submitted herewith for filing is the Patent Application of:

Inventor: MOU-SHIUNG LIN

For: WAFER SCALE PACKAGING SCHEME

1c540 U.S. PTO  
09/13/1429  
08/10/98

Enclosed are:

- ☒ 6 sheets of formal drawing(s).  
☐ An assignment of the invention to  
☐ An associate power of attorney  
☒ Small Entity Status

The filing fee has been calculated as shown below:

|                                    | (Col. 1)  | (Col. 2)  | SMALL ENTITY |        |
|------------------------------------|-----------|-----------|--------------|--------|
| FOR:                               | NO. FILED | NO. EXTRA | RATE         | FEE    |
| BASIC FEE                          |           |           |              | \$395  |
| TOTAL CLAIMS                       | 36 -20=   | 16        | x 11.=       | \$176. |
| INDEP CLAIMS                       | 5 -3=     | 2         | x 41.=       | \$82.  |
| MULTIPLE DEPENDENT CLAIM PRESENTED |           |           | + 260 =      |        |
|                                    |           |           | SUB TOTAL    | \$653. |
|                                    |           |           | ASSIGNMENT   |        |
|                                    |           |           | TOTAL        | \$653. |

- ☒ Please charge my Deposit Account No. 19-0033 in the amount of \$ 653. A duplicate copy of this sheet is enclosed.
- ☒ The Commissioner is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account No. 19-0033. A duplicate copy of this sheet is enclosed.
- ☒ Any additional filing fees required under 37 CFR \$1.16.
- ☒ Any patent application processing fees under 37 CFR \$1.17.

Respectfully submitted,  
*George D. Saile*  
GEORGE D. SAILE, REG. NO. 19,572

**STATEMENT CLAIMING SMALL ENTITY STATUS  
(37 CFR 1.9(f) & 1.27(b))--INDEPENDENT INVENTOR**

Docket Number (Optional)

MSLIN98-001

Applicant, Patentee, or Identifier: MOU-SHIUNG LIN

Application or Patent No.: \_\_\_\_\_

Filed or Issued \_\_\_\_\_

Title: WAFER SCALE PACKAGING SCHEME

As a below named inventor, I hereby state that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

- ☒ the specification filed herewith with title as listed above.
- ☐ the application identified above.
- ☐ the patent identified above.

I have not assigned, granted, conveyed, or licensed, and am under no obligation under contract or law to assign, grant, convey, or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern, or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- ☒ No such person, concern, or organization exists.
- ☐ Each such person, concern, or organization is listed below.

Separate statements are required from each named person, concern, or organization having rights to the invention stating their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

Mou-Shiung Lin  
NAME OF INVENTOR

NAME OF INVENTOR

NAME OF INVENTOR

Mou-Shiung Lin  
Signature of inventor

Signature of inventor

Signature of inventor

August 4th, 1998  
Date

Date

Date

## WAFER SCALE PACKAGING SCHEME

### FIELD OF THE INVENTION

The invention relates to the general field of integrated circuit packaging with particular reference to low cost methods for packaging individual chips.

### BACKGROUND OF THE INVENTION

Manufacturing techniques in use in the semiconductor industry have continued to improve in efficiency with resulting drops in cost. This is particularly true for chip manufacturing where the cost per gate continues to drop year by year. Some of this advantage is, however, offset by the somewhat slower pace at which the cost of chip packaging has been dropping. Until recently, chip manufacture and chip packaging have been treated as essentially separate technologies and advances in the former have not necessarily added value to the latter.

Recently, wafer scale packaging has been gaining in popularity. By this we mean that the entire wafer is packaged prior to its being separated into individual chips. A good example of this has been a recent publication by M. Hou "Wafer level packaging for CSPs"

MSLIN98-001

in Semiconductor International, July 1998 pp. 305-308. CSPs (chip scale packages) first made their appearance around 1996. Since then there have been a number of improvements exemplified by the structure described by Hou. In the process that she discusses, assembly of individual chip packages becomes an extension of the wafer fabrication line rather than a separate operation dedicated to chip packaging.

Briefly, the process that is described by Hou involves compression molding of an encapsulant onto the top surface of the full wafer. A special molding press, custom built to fit each type of wafer that is to be used, is needed and reliance is made on the ability of the solder bumps, already present on the top surface of the completed wafer, to push through the plastic and reappear at the top surface of the package. Hou notes that this approach is suited primarily to low density packages.

## SUMMARY OF THE INVENTION

It has been an object of the present invention to provide a package and a process for packaging semiconductor chips.

An additional object of the invention has been that said process result in the simultaneous packaging of all chips on a single wafer at the same time.

A still further object of the invention has been that said process not require any special jigs or fixtures for its implementation.

Yet another of object of the invention has been that said process be suitable for packages having a high density of interconnections.

One more object of the invention has been that said process provide packages that are significantly cheaper than those obtained through individual chip packaging processes.

These objects have been achieved by depositing a layer of a polymeric material, such as polyimide, silicone elastomer, or benzocyclobutene on the surface of the chip. Via holes through this layer connect to the top surfaces of the studs that pass through the passivating layer of the chip. In one embodiment, the polymeric layer covers a redistribution network on a previously planarized surface of the chip. Individual chip-level networks are connected together in the kerf so that conductive posts may be formed inside the via holes through electroplating. After the formation of solder bumps, the wafer is diced into individual chips thereby isolating the individual redistribution networks. In a second embodiment, no redistribution network is present. In a third embodiment, there is also no redistribution network but electroplating is made possible by using a contacting layer. The polymeric layer then also serves as the final planarizing layer. Conductive posts are then formed in the via holes by means of electroless plating.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a is a schematic cross-section of a fully packaged integrated circuit including a top layer of polymeric material that communicates to the chip level through extended via holes and a redistribution network.

FIG. 1b is a schematic cross-section of a fully packaged integrated circuit including a top layer of polymeric material that communicates directly to the chip level through extended via holes.

FIG. 2 shows parts of an integrated circuit prior to packaging.

FIG. 3 shows the structure of FIG. 2 after the addition of a planarizing layer that includes an access hole to the studs as well as a contacting layer.

FIG. 4 shows the structure of FIG. 3 following the addition of a redistribution layer.

FIG. 5 shows structure of FIG. 4 following the addition of a layer of polymeric material in which a via hole has been formed.

FIG. 6 is the structure seen in FIG. 5 after the via hole has been overfilled with metal to form a conducting post.

FIG. 7a shows the structure of FIG. 6 following the formation of a solder ball at the end of a projecting post together with etchback to form a 'lollipop' structure.

FIG. 7b is like FIG. 7a except that a layer of UBM has been inserted between the solder ball and the polymeric layer.

FIG. 8 shows the structure of FIG. 2 following the addition of a layer of polymetric material in which a via hole has been formed directly above the stud.

FIG. 9 is the structure seen in FIG. 8 after the via hole has been overfilled with metal to form a conducting post.

FIG. 10a shows the structure of FIG. 9 following the formation of a solder ball at the end of a projecting post.

FIG. 10b is like FIG. 10a except that a layer of UBM has been inserted between the solder ball and the polymeric layer.

FIGs. 11a and 11b illustrate how the shape of a via hole formed in a photosensitive material may be modified depending on its properties and on the exposure mode used.

MSLIN98-001

FIG. 12 shows how individual redistribution networks on chips may be connected together in the kerf to form a single common distribution network.

FIG. 13 shows a freestanding post which is to be almost covered by a layer of polymeric material.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention teaches a process and a package for encapsulating an entire wafer with a layer of a polymeric material which is applied by any of several conventional techniques such as spin coating, dipping, spraying, or as a dry film and describes several low-cost ways of establishing electrical communication between terminals at the surface of the chip and solder bumps on the outer surface of the package. We will describe two embodiments of the invention. In the first of these embodiments electroplating is used to form parts of the package but it should be understood that electroless plating may be substituted for selected subprocesses without departing from the spirit of the invention.

In FIG. 1a we show a schematic representation of one embodiment. An integrated circuit is shown in cross-section as a series of layers that have been formed over silicon substrate 1. Successive layers 2, 3, and 4 represent the device level and two levels of wiring respectively. Each layer has been planarized. The top-level wiring, including I/O



pads such as 6 and 7 has been formed on the top surface of layer 4 and then covered by passivating layer 13 (usually silicon nitride) which in turn has been covered by a final planarizing layer 5 (typically, but not necessarily, of polyimide). In general, the pattern of studs 8 will not coincide with the pattern of solder terminals on the card or board to which the chip is to be attached. It is also possible that more than one pattern of the ball grid array (BGA) on the outer surface of the package is needed, depending on where this particular chip is to be attached. In order to deal with this, it is standard to use a redistribution network, normally located on the top surface of planarizing layer 5. A part of the redistribution network is exemplified by layer 14. An additional feature of packages of this type (not shown in FIG. 1a but illustrated in later figures) is a contacting layer at the interface between layers 5 and 10.

Using conventional manufacturing techniques, the chip manufacturing process for a standard flip chip would normally terminate at this point. In the wafer scale packaging approach, the process is continued with the application of a plastic (polymeric) layer 10 that gives the chip both environmental as well as mechanical protection. In order to be able to make electrical contact to layer 14, via holes 11, filled with a suitable conductive material, need to be formed and fresh solder bumps 12 attached to their top ends.

FIG. 1b is a schematic view of a second embodiment, representing a lower cost version of the package. It differs from FIG. 1a in that no redistribution network is present.

MSLIN98-001

This implies that the pattern of connecting studs is the same as the pattern of solder terminals on the next level package. This simplification allows final planarization layer 5 (in FIG. 1a) to be omitted from the structure. Instead, polymeric layer 15 is allowed to extend all the way down to passivating layer 13.

We have identified three types of polymeric material that are suitable for wafer scale packaging of the type disclosed in the present invention. These are polyimides, silicone elastomers, and benzocyclobutene (BCB). All three types are readily applied by spin coating while in their uncured form and they may then be hardened (cured) through reaction with a hardening agent, usually, but not necessarily, accelerated by heating. Additionally, the polyimides are available in the form of dry films which can be applied directly to a surface by means of an adhesive. The choice of which material to use depends on a number of factors. These include:

Temperature coefficient of expansion (TCE) — should be low so as to match that of the metal studs, thereby minimizing local stresses at the stud-polymer interface

Young's modulus (degree of inelasticity)  $Y$  — should be low to reduce transmission of stress to the posts and to decouple the thermal mismatch between silicon and plastic

Water absorption — should be low to ensure stability

Moisture permeability — should be low to protect the semiconductor

Adhesion — should be high

Electrical properties, such as dielectric constant, dielectric loss, resistivity, etc. tend

MSLIN98-001

to be adequate for all three of these materials.

It is thus apparent that selection of the correct polymeric material will depend on a number of factors such as layer thickness, anticipated temperature range during life, atmosphere to which package will be exposed, BGA density, chip size, I/O count, etc. Additionally, as noted below, use of the photosensitive versions of these materials offer several advantages, including the ability to tailor the shape of the via holes, so when such versions are readily available commercially (as in the case of polyimides and BCB) this must also be considered.

In TABLE I below we summarize some of the properties of these materials.

The numbers given represent averages for the class of materials :-

| PROPERTY         | POLYIMIDES                            | ELASTOMERS                           | BCB                                   |
|------------------|---------------------------------------|--------------------------------------|---------------------------------------|
| Cure temperature | 350° C                                | room temperature                     | 250 ° C                               |
| Young's modulus  | 3.4 Gpa                               | very small                           | 2 GPa                                 |
| Water absorption | 3%                                    | low                                  | 0.2%                                  |
| TCE              | $40 \times 10^{-6} / ^\circ \text{C}$ | $1 \times 10^{-6} / ^\circ \text{C}$ | $52 \times 10^{-6} / ^\circ \text{C}$ |
| Adhesion         | fair to good                          | Good - excellent                     | Fair to good                          |

TABLE I

Even if the polymeric layer is able to absorb stress inherent to the design without, for example, cracking, it is also necessary for the metal posts that fill the via holes to exhibit

MSLIN98-001

good elastic behavior so that, if need be, they can bend rather than break. It can be shown that a metal post of length L, fixed at one end and free at the other, requires a force F to displace it by an amount d at the free end. The magnitude of F is calculated according to the equation:

$$F = (3YId)/L^3, \text{ where } Y = \text{Young's modulus and } I = \text{moment of inertia}$$

Thus, to minimize the force required to cause a given displacement (i.e. for the post to be flexible), both Y and I need to be minimized. As far as Y is concerned, gold and solder are good choices although copper is to be preferred for other reasons, while I is proportional to the mass of the post, implying that a small diameter and low density are best.

We will now describe the three embodiments of the invention. Although these embodiments differ in their total approach they both share the following initial steps:

Referring now to FIG. 2, all embodiments begin with the provision of a semiconductor wafer in which multiple chips have been formed. Each such chip has an image on the surface of the wafer and each such chip image is separated from all others by a region known as the kerf because it will be used later by the saw blade for dicing the wafer into individual chips. Integrated circuit 21 is shown as having been formed over silicon substrate 20. Layer 22 represents a passivating layer similar to layer 13 in FIGs. 1a

MSLIN98-001

and 1b, while connecting pad 23 (corresponding to stud 7 in FIG. 1a) is seen as being open to the outside world.

### FIRST EMBODIMENT

In FIG. 3, layer 30 represents everything in FIG. 2 below the pad 23, including layer 22. Layer 31 of polyimide has been deposited by spin coating onto the surface of 30 and opening 32 has been formed in it using standard photolithographic techniques, including photosensitive polyimides. Layer 31 is generally between about 3 and 20 microns thick. This is followed by the deposition of layer 33 of chrome-copper generally but not necessarily, by sputtering, to a thickness that is between about 500 and 2,000 Angstroms.

With layer 33 (in FIG. 3) covering the entire surface of the wafer, photoresist is laid down and patterned so that the surface is covered everywhere except where it is intended to have the redistribution network. In an important feature of the invention, the individual chip-level distribution networks are connected to one another by using the otherwise empty space provided by the kerf, thereby forming a common distribution network as illustrated in FIG. 12 where individual redistribution networks in chip images 93 - 96 are seen to be connected together in the kerf regions 98 thereby forming a common distribution network one end of which is designated as 99.

Electroplating is then used to build up the thickness of the metal that forms the common distribution network. Electrical contact is made to metal layer 33 allowing metal to be plated in all areas not covered by the photoresist. For this metal we have preferred to use copper although metals such as aluminum could also have been used together with non-electroplating methods. At the completion of electroplating, resulting in an additional thickness of metal between about 0.5 and 5 microns thick, the photoresist is removed. An example of part of the redistribution network is shown as layer 41 in FIG. 4 and all parts of the contacting layer not covered by the redistribution network are selectively removed.

Next, a layer of polymeric material is laid down. This is shown as layer 51 in FIG. 5. Its thickness is between about 20 and 250 microns. Via hole 52 is then formed in it. This corresponds to via holes 11 in FIG. 1a. Several different subprocesses were available for the formation of this via hole:

(a) the polymeric material is photosensitive. In the case of BCB and the polyimides, there are many commercial compositions available for this. Via holes 52 are then formed by exposing through a suitable mask and developing. By controlling the type of photosensitive materials as well as the exposure conditions, the shape of the via holes can be controlled. For example, if the photosensitive material generates a negative image of the mask this can cause the via holes to be wider closest to their bottom, i.e. closest to layer 41 as illustrated in FIG. 11a. On the other hand, if the photosensitive material generates a positive image of the mask and if an imaging system with a low depth of focus is used and if the image is focused in a plane midway between the two surfaces, the effect

is for the via holes to be narrowest at a point halfway down the holes, as illustrated in FIG. 11b. In general, the resulting conductive posts will have better strength and adhesion than conventional (simple cylindrical) posts.

(b) the polymeric material is etched in the usual way using a photoresist mask. Since the photoresist and the polymeric material respond somewhat similarly to the etchants usually used for the latter, a hard mask (e.g. CVD silicon oxide) is often used.

(c) the polymeric material is etched using laser drilling. For polymeric layers thicker than about 100 microns this is the preferred method. An example of a laser well suited to this application is an excimer (209 nm) laser or a CO<sub>2</sub> (10.6 microns) laser with the capability of forming holes with diameters as low as about 50 microns.

Then, using a second electroplating step (contact to layer 41 being made through the common distribution network), additional metal (preferably copper but other metals such as gold, solder (such as lead-tin), or aluminum (non-electroplated), could also have been used) was plated onto all exposed surfaces of layer 41. In other words, via hole 52 was filled with metal, with post formation being continued past the point at which it was just filled. Thus the appearance of the structure following the overfilling of via hole 52 approximated that shown schematically in FIG. 6 where stud 67 is seen to have a rounded top projecting above the surface of layer 51. This projection of the post above the polymeric material surface is needed to anchor the solder bumps which are grown in the next step of the process. This 'anchor' effect can be further enhanced by etching back the polyimide material to some extent, as illustrated in FIG. 7a, to generate a 'lollipop' structure for the

MSLIN98-001

post-bump combination.

Referring now to FIG. 7a, a solder bump such as 71 is grown over the projecting tip of 67. Since electrical contact can still be made to 67 through the common distribution network, electroplating is the preferred method for accomplishing this. In general, electroplating offers better control, in particular control of the composition of the deposited layer, than is achievable by, for example, electroless plating.

As a variation to this embodiment, the extensions of the posts may be first coated with a UBM layer 72 as shown in FIG. 7b prior to growing solder bump 71. This is done in the usual manner by first depositing over the entire surface and then patterning and etching. The advantage of providing this extra layer of UBM is that the base contact area for the solder balls is enlarged and hence their adhesion is increased. It would be used in cases where large solder balls are required. In both cases, the diameter of the solder bumps was between about 100 and 300 microns with a pitch that was typically between about 200 and 800 microns.

Once solder bumps 71 have been formed, the wafer is diced into individual chips by cutting along the kerf. In so doing the common distribution network is destroyed but each chip retains its own individual redistribution network.



## SECOND EMBODIMENT

Unlike the first embodiment, there is no redistribution network present on the surface of the unpackaged chips. Therefore, the process proceeds directly from the structure of FIG. 2 to the step of laying down a layer of polymeric material 80 (as illustrated in FIG. 8) whose thickness is between about 20 and 250 microns. As in the first embodiment, via holes 82 are formed in it with the added constraint that they are located directly above studs 23. These correspond to the via holes that will contain conductive posts 11 in FIG. 1b. In order to form these via holes, one of three subprocesses were used:

(a) the polymeric material is photosensitive. In the case of polyimides or BCB, there are many commercial compositions available for this. Via holes 52 are then formed by exposing through a suitable mask and developing. By controlling the type of photosensitive material as well as the exposure conditions, the shape of the via holes can be controlled. For example, if the photosensitive material generates a negative image of the mask this can cause the via holes to be wider closest to their bottom, i.e. closest to layer 41 as illustrated in FIG. 11a. On the other hand, if the photosensitive material generates a positive image of the mask and if an imaging system with a low depth of focus is used and if the image is focused in a plane midway between the two surfaces, the effect is for the via holes to be narrowest at a point halfway down the holes as illustrated in FIG. 11b.

(b) the polymeric material is etched in the usual way using a photoresist mask. Since the photoresist and the polymeric material respond somewhat similarly to the etchants usually used for the latter, a hard mask (e.g. CVD silicon oxide) is often used .

(c) the polymeric material is etched using laser drilling. For polymeric layers thicker than about 100 microns this is the preferred method. An example of a laser well suited to this application is an excimer (209 nm) laser or a CO<sub>2</sub> (10.6 microns) laser with the capability of forming holes with diameters as low as about 50 microns.

Then, using electroless plating, (electrical contact to I/O pads such as 6 or 7 not being available in this embodiment), additional metal (preferably copper but other metals such as gold, solder, or nickel could also have been used) was plated onto all exposed surfaces of studs 23. In other words, via hole 82 was filled with metal.

The filling of 82 was continued past the point at which it was just filled. Thus the appearance of the structure following the overfilling of via hole 82 approximated that shown schematically in FIG. 9 where post 87 is seen to have a rounded top projecting above the surface of layer 80. As in the first embodiment, this projection of the post above the polymeric material surface is needed to anchor the solder bumps which are grown in the next step of the process.

Referring now to FIG. 10a, a solder bump 81 is grown over the projecting tip of 87. Since electrical contact cannot be made to 87, electroless plating has to be used.

MSLIN98-001

As a variation to this embodiment, the extensions of the posts may be first coated with a UBM layer 88 (as shown in FIG. 10b) prior to growing solder bump 81. This is done in the usual manner by first depositing over the entire surface and then patterning and etching. The advantage of providing this extra layer of UBM is that the base contact area for the solder balls is enlarged and hence their adhesion is increased. It would be used in cases where large solder balls are required. In both cases, the diameter of the solder bumps was between about 100 and 300 microns with a pitch that was typically between about 200 and 800 microns.

As an alternative, low cost, variation, instead of forming the solder bumps through plating, they may be laid down by means of screen printing or stenciling. This is a viable approach for solder bumps having diameters in excess of about 100 microns with a pitch that is greater than about 200 microns.

Once solder bumps 81 have been formed, the wafer is diced into individual chips by cutting along the kerf.

### THIRD EMBODIMENT

As in the second embodiment, there is no redistribution network present on the surface of the unpackaged chips. However, unlike the second embodiment, the preferred

MSLIN98-001

metal deposition method is electroplating. Accordingly, a contacting metal layer is deposited over the entire passivation layer. See layer 45 in FIG. 13. This is followed by coating with a layer a photoresist in which via holes are formed in a similar manner to the formation of via holes in the photosensitive versions of the polymers as described in the first and second embodiments, including techniques for controlling the shapes of these via holes. The via holes are then filled with metal by means of electroplating following which the photoresist is stripped, leaving behind freestanding metal posts such as 46 in FIG. 13.

Then, using a differential etch, the contacting layer is removed without any attack on the freestanding posts. Next, the polymeric material is applied to the wafer as a single layer whose thickness is less than the height of the freestanding posts, thereby allowing a certain amount of uncovered post material to project above the surface of the polymer. The structure is then completed as in the second embodiment through the formation of solder bumps by electroless plating, screen printing, or stenciling.

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

What is claimed is:

MSLIN98-001

1. A process for wafer scale packaging, comprising:

providing a semiconductor wafer, including chip images separated by a kerf area and

having a topmost passivating layer through which pass connecting studs;

forming a polymeric body having a plurality of metal posts in contact with, and fixed

5 to, said connecting studs and passing vertically through said polymeric body from said studs; and

wherein said posts are of a diameter and height and of a material that they can bend to absorb stress due to thermal mismatch between said semiconductor wafer and said polymeric body.

10 2. The process of claim 1 wherein said polymeric body is a polyimide or a silicone elastomer or benzocyclobutene.

3. The process of claim 1 further comprising forming via holes in said polymeric body and then forming the conducting posts inside the via holes.

15 4. The process of claim 3 wherein said via holes are formed by chemical etching or by laser drilling.

5. The process of claim 3 wherein said metal posts of formed by electroplating or by electroless plating.

6. The process of claim 1 wherein a bending force exerted at a free end of a metal post of length L displaced by an amount d, is according to a formula  $F = (3YId)/L^3$ , where Y = Young's modulus and I = moment of inertia.

7. The process of claim 1 wherein said polymeric body is laid down by spin coating or by dipping or by spraying or in the form of a dry film with an adhesive undercoating.

8. A process for wafer scale packaging, comprising the sequential steps of:

(a) providing a semiconductor wafer, including chip images separated by a kerf area and having a topmost passivating layer through which pass connecting studs;

(b) depositing a planarizing layer of polyimide over the passivating layer and then patterning and etching said polyimide layer to form openings over the connecting studs;

(c) depositing a UBM layer on said polyimide layer, depositing a first layer of photoresist on the UBM layer, and then patterning the photoresist to leave uncovered areas of the UBM layer that define a common distribution network comprising chip-level redistribution networks connected to each other in the kerf;

(d) by means of electroplating, depositing a first layer of metal on all areas of the UBM layer not covered by photoresist;

(e) removing the first layer of photoresist and selectively removing all parts of the UBM layer that are not covered by said first layer of metal;

(f) laying down a layer of polymeric material and forming therein via holes that extend down to the level of the common distribution network;

(g) by means of electroplating, depositing a second layer of metal on all metallic areas not covered by the second layer of polymeric material until the via holes have been overfilled with said second metal layer, thereby forming posts with projections that extend by an amount above the layer of polymeric material;

5 (h) by means of electroplating, forming solder bumps centered around and attached to, said post projections; and

(i) slicing the wafer into individual chips, thereby cutting all lines in the kerf area and electrically dividing said common distribution network into chip-level redistribution networks.

9. The process of claim 8 wherein said polymeric body is a polyimide or a silicone elastomer or benzocyclobutene.

10. The process of claim 8 wherein said polymeric body is a layer having a thickness of between about 20 and 250 microns.

11. The process of claim 8 wherein the step of forming via holes in the layer of polymeric material further comprises using a photo sensitive version of the polyimetric material which is exposed through a mask and then developed to form the holes.

12. The process of claim 8 wherein the step of forming via holes in the layer of polymeric material further comprises using a photoresist mask in conjunction with a hard mask over the polymeric material and then etching the polymeric material.

MSLIN98-001

13. The process of claim 8 wherein the step of forming via holes in the layer of polymeric material further comprises using laser drilling.

14. The process of claim 8 wherein said second metal layer has a thickness between about 20 and 250 microns and is selected from the group of consisting of copper, gold, solder, and aluminum .

15. The process of claim 11 wherein said photosensitive version provides a negative image of the mask which causes the via holes to be wider closest to the second layer of metal.

16. The process of claim 11 further comprising:

using a photosensitive version of the polymeric material that provides a positive image of the mask and that has upper and lower surfaces;

employing an imaging system that has a low depth of focus; and

focusing in a plane midway between said surfaces, thereby causing said via holes to be narrowest at a point halfway down the holes.

17. The process of claim 8 further comprising etching back the layer of polymeric material to generate a lollipop structure from the post and solder bump combination.

18. The process of claim 8 further comprising coating the uncovered portions of the



posts with a UBM layer before forming the solder bumps.

19. A process for wafer scale packaging, comprising the sequential steps of:

(a) providing a semiconductor wafer containing integrated circuits, including a topmost passivating layer through which pass conductive studs that connect to points within said integrated circuits;

(b) laying down a layer of polymeric material and forming therein via holes that overlie and extend down to said conductive studs;

(c) by means of electroless plating, depositing a layer of metal on all metallic areas not covered by polymeric material until the via holes have been overfilled with said metal layer thereby forming posts with projections that extend above the layer of polymeric material by an amount;

(d) by means of electroless plating, forming solder bumps centered around and attached to, said post projections; and

(e) slicing the wafer into individual chips.

20. The process of claim 19 wherein said polymeric body is a polyimide or a silicone elastomer or benzocyclobutene.

21. The process of claim 19 wherein said polymeric body is a layer having a thickness of between about 20 and 250 microns.

MSLIN98-001

22. The process of claim 19 wherein the step of forming via holes in the layer of polymeric material further comprises using a photosensitive version of the polymeric material which is exposed through a mask and then developed to form the holes.

23. The process of claim 19 wherein the step of forming via holes in the layer of polymeric material further comprises using a photoresist mask, together with a hard mask, over the polymeric material and then etching the polymeric material.

24. The process of claim 19 wherein the step of forming via holes in the layer of polymeric material further comprises using laser drilling.

25. The process of claim 22 wherein said photosensitive version provides a negative image of the mask which causes the via holes to be wider closest to the second layer of metal.

26. The process of claim 22 further comprising:

using a photosensitive version of the polymeric material that provides a positive image of the mask and that has upper and lower surfaces;

employing an imaging system that has a low depth of focus; and

focusing in a plane midway between said surfaces, thereby causing said via holes to be narrowest at a point halfway down the holes.

MSLIN98-001

27. The process of claim 19 wherein the amount that the posts project above the layer of polymeric material is between about 10 and 75 microns.

28. The process of claim 19 further comprising coating the uncovered portions of the posts with a UBM layer before forming the solder bumps.

29. The process of claim 19 wherein, in step (d) instead of electroless plating, the solder bumps are laid down using screen printing or stenciling.

30. A process for wafer scale packaging, comprising the sequential steps of:

(a) providing a semiconductor wafer containing an integrated circuit, including a topmost passivating layer through which pass conductive studs that connect to points within said integrated circuits;

(b) depositing a contacting layer of metal over the passivating layer;

(c) laying down a layer of photoresist and forming therein via holes that extend down to the contacting metal layer;

(d) by means of electroplating, depositing a layer of metal on all contacting metal areas not covered by photoresist until the via holes have been filled with said metal layer;

(e) removing the layer of photoresist, thereby forming freestanding metal posts;

(f) without attacking said posts, removing the contacting metal layer;

(g) spreading over the entire wafer a layer of polymeric material whereby part of the posts remain uncovered;

MSLIN98-001

(h) forming solder bumps centered around and attached to, said post projections;  
and

(i) slicing the wafer into individual chips.

31. A wafer scale package, comprising:

a semiconductor wafer, including chip images separated by a kerf area and having a topmost passivating layer through which pass connecting studs;

a polymeric body having a plurality of metal posts in contact with, and fixed to, said connecting studs and passing vertically through said polymeric body from said studs; and

wherein said posts are of a diameter and height and of a material that they can bend to absorb stress due to thermal mismatch between said semiconductor wafer and said polymeric body.

32. The package of claim 31 wherein said polymeric body is a polyimide or a silicone elastomer or benzocyclobutene.

33. The package of claim 31 wherein said polymeric body has a thickness between about 20 and 250 microns.

34. The process of claim 31 wherein said metal posts have a width between about 10 and 200 microns.

MSLIN98-001

35. The process of claim 31 wherein said metal posts are plated copper.

36. The package of claim 31 wherein a bending force exerted at a free end of a metal post of length  $L$ , displaced by an amount  $d$ , is according to a formula  $F = (3YId)/L^3$ , where  $Y$  = Young's modulus and  $I$  = moment of inertia.

## ABSTRACT

A process and a package for achieving wafer scale packaging is described. A layer of a polymeric material, such as polyimide, silicone elastomer, or benzocyclobutene is deposited on the surface of a chip. Via holes through this layer connect to the top surfaces of the studs that pass through the passivating layer of the chip. In one embodiment, the polymeric layer covers a redistribution network on a previously planarized surface of the chip. Individual chip-level networks are connected together in the kerf so that conductive posts may be formed inside the via holes through electroplating. After the formation of solder bumps, the wafer is diced into individual chips thereby isolating the individual redistribution networks. In a second embodiment, no redistribution network is present so electroless plating is used to form the posts. In a third embodiment, there is also no redistribution network but electroplating is made possible by using a contacting layer. Solder bumps attached to the posts are then formed by means of electroless plating, screen or stencil printing.

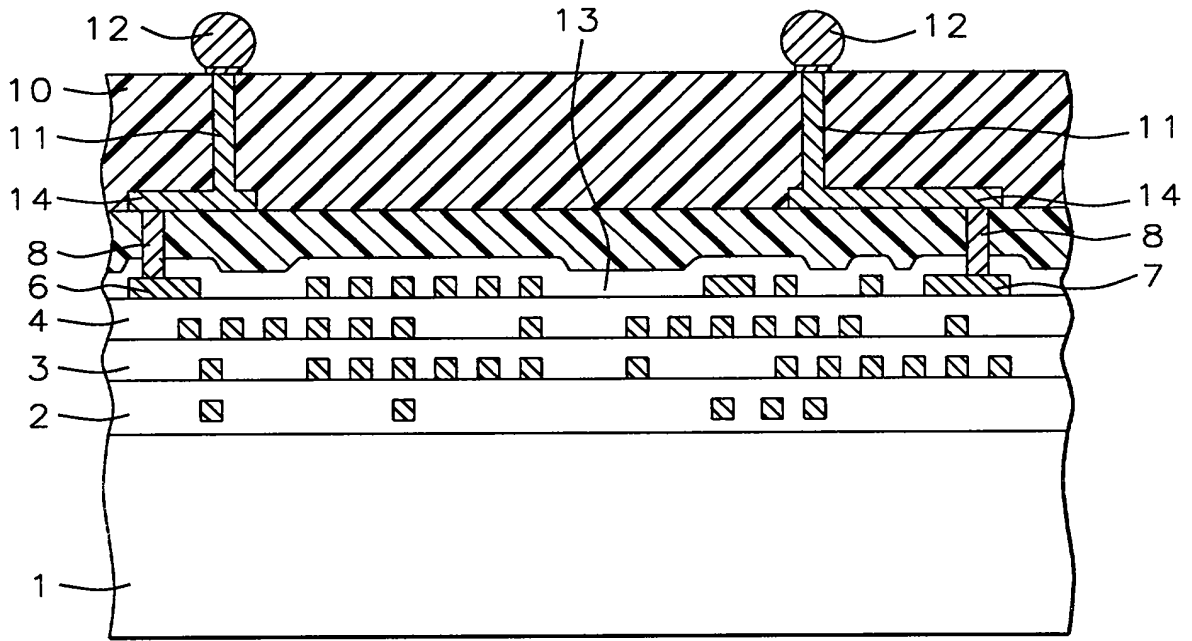


FIG. 1a

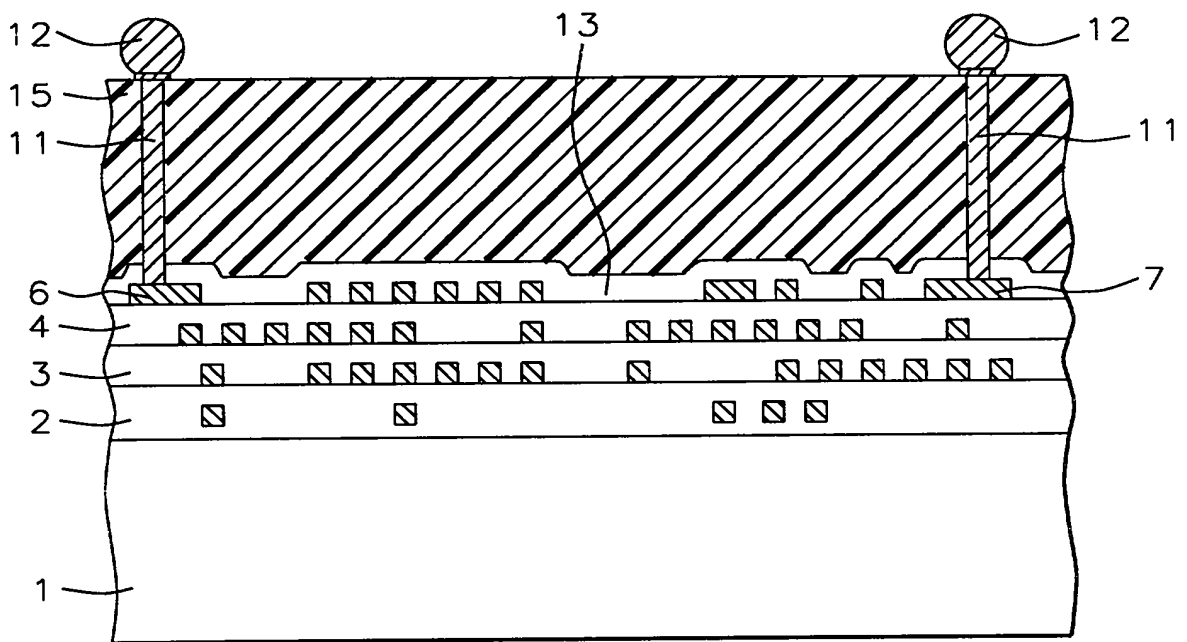


FIG. 1b

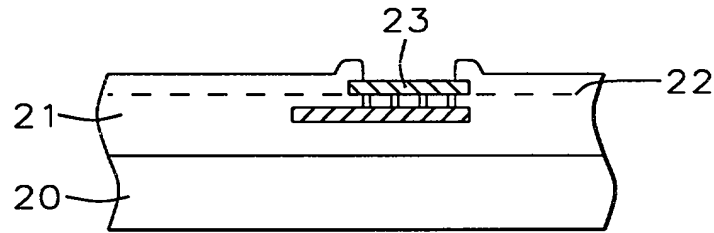


FIG. 2

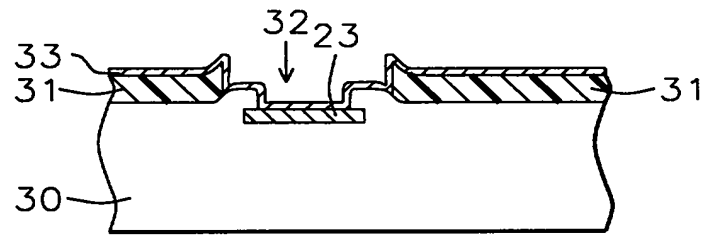


FIG. 3

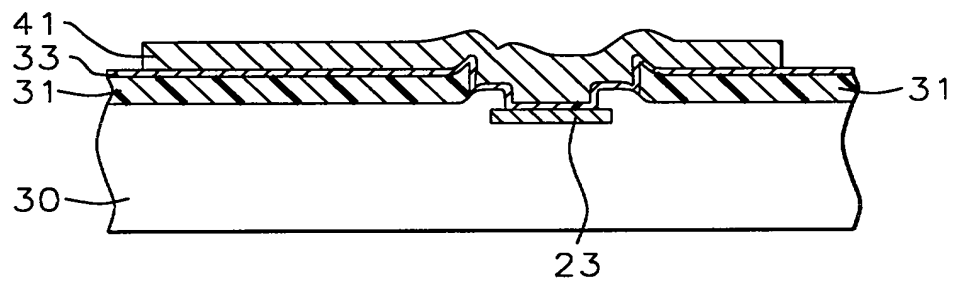


FIG. 4

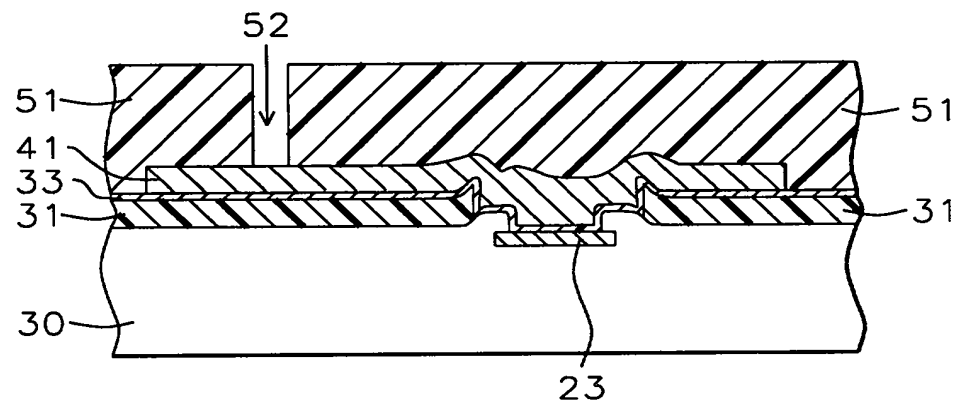


FIG. 5



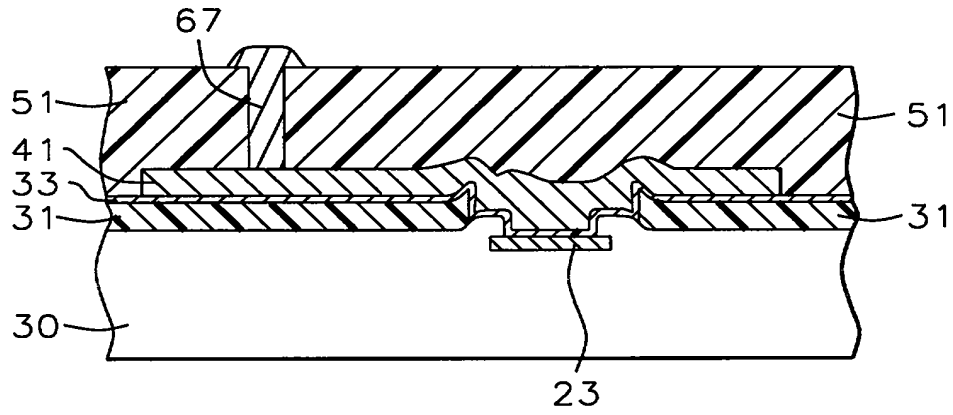


FIG. 6

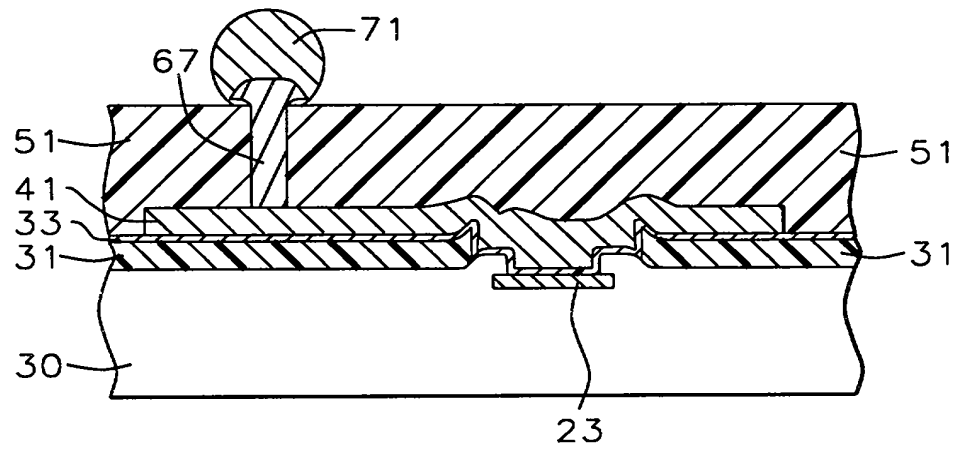


FIG. 7a

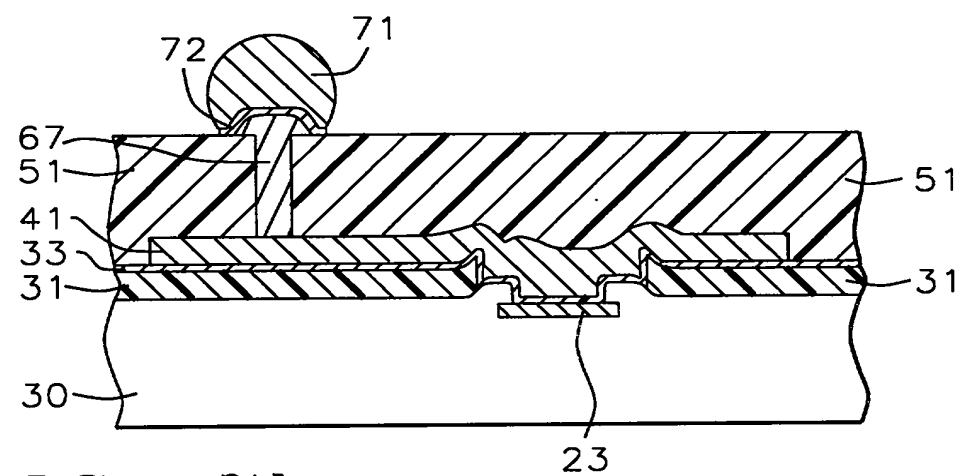
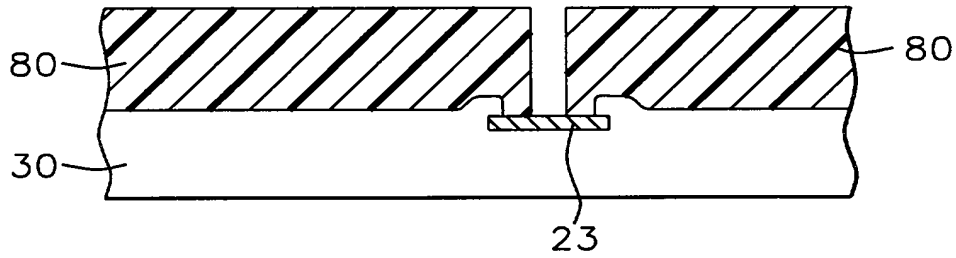
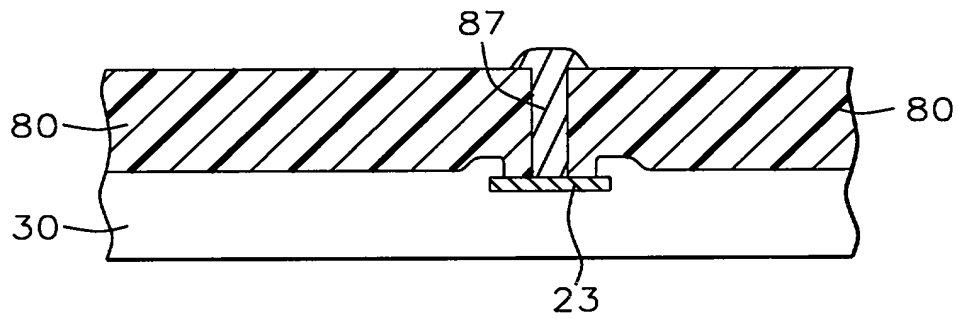
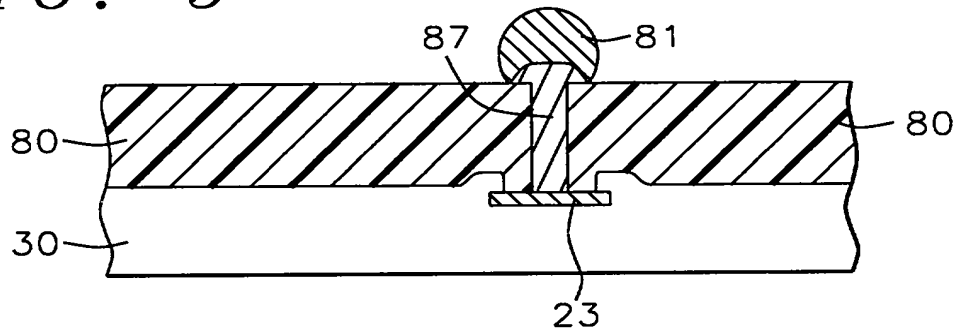
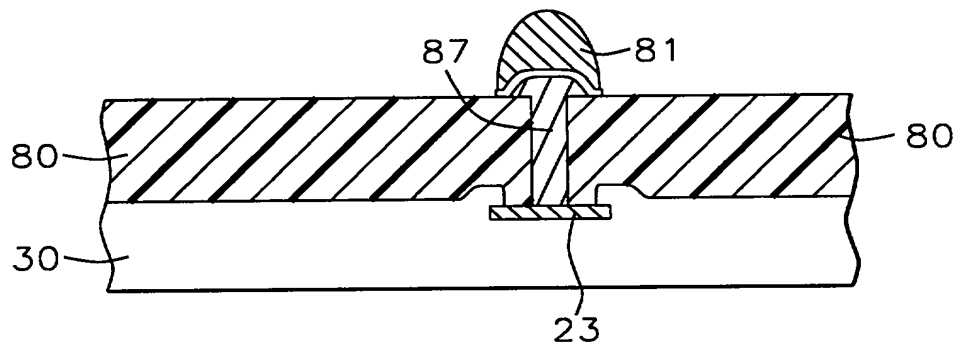


FIG. 7b

*FIG. 8**FIG. 9**FIG. 10a**FIG. 10b*

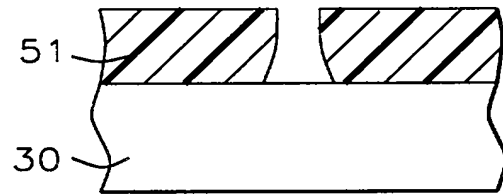


FIG. 11a

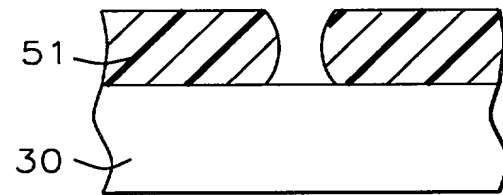


FIG. 11b

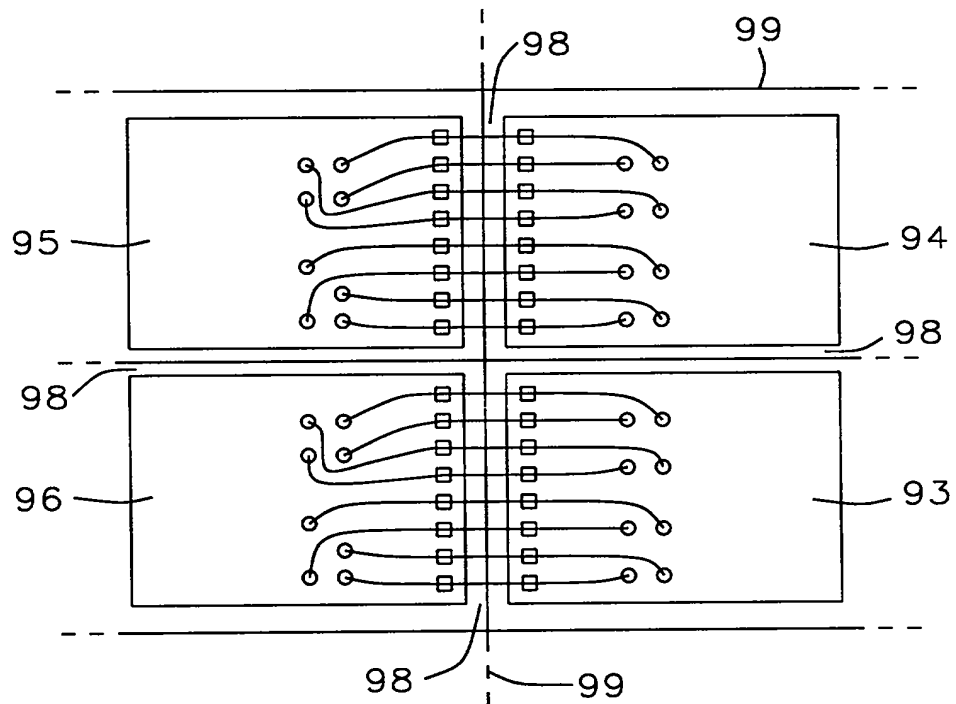
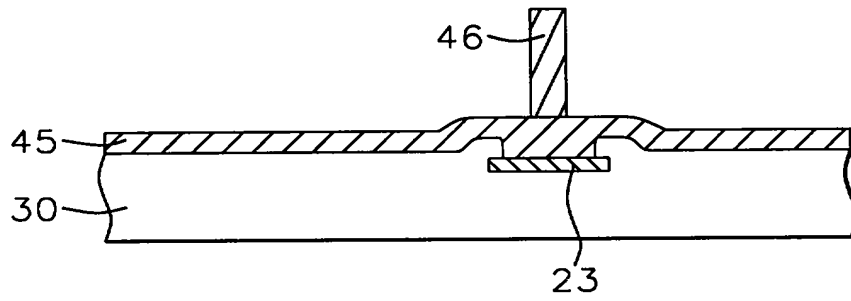


FIG. 12



*FIG. 13*

## DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

DOCKET NO. MSLIN28-001

As a below named Inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled  
**Wafer Scale Packaging Scheme**

the specification of which (check one)

☒ X is attached hereto.

was filed on \_\_\_\_\_

Application Serial No. \_\_\_\_\_

and was amended on \_\_\_\_\_  
(if applicable)

I hereby state that I have reviewed and understand the contents of the above Identified specification including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed:

| (Number) | (Country) | (Day/Month/Year Filed) |
|----------|-----------|------------------------|
|          |           |                        |
| (Number) | (Country) | (Day/Month/Year Filed) |

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

| (Application Serial No.) | (Filing Date) | (Status) (patented, pending, abandoned) |
|--------------------------|---------------|---|
|--------------------------|---------------|---|

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name &amp; registration no.)

GEORGE O. SAILE. (Reg. No. 19,572), STEPHEN B. ACKERMAN (Reg. No. 37,761)

Send Correspondence to: 20 MCINTOSH DRIVE, POUGHKEEPSIE, NEW YORK 12603

Direct telephone Calls to: (name &amp; telephone number) GEORGE O. SAILE NEW YORK 914 452 5863

Full name of sole or first inventor Mou-Shiung Lin Date August 3rd, 1998Inventor's signature Mou-Shiung LinResidence 24 Bamboo 3rd Rd., 6F, Hsinchu, TaiwanCitizenship USAPost Office Address 24 Bamboo 3rd Rd., 6F, Hsinchu, Taiwan